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Computerized Maintenance Management System: A case of Process Industries of Pakistan

Muhammad Hassan Ali, Rameez Khalid

Institute of Business Administration Karachi

* **Corresponding Author:** Email: rameezkhalid@iba.edu.pk

Abstract

Maintenance, a fundamental of reliable operations, has gone through an evolution from reactive to proactive strategies. In this evolution, the technology layer has been added in terms of computerized maintenance management system (CMMS). This paper aims to explore the current status of CMMS in the process industries of a developing country. For this study, data were collected via questionnaire from 62 publicly listed companies along with an analysis of their annual reports. Moreover, six interviews of CMMS consultants were conducted. It was found that 56% of the sampled companies had a CMMS running, while 44% had no such solution. The key performance indicator (KPI) of '% replacement asset value' (%RAV) was further determined, which was found to be 3.74% for companies with CMMS and 5.67% for companies with no CMMS; considering the global benchmark of 2.5%. The challenges to CMMS implementation included unawareness about function of CMMS, erroneous data and weak change management. Even in companies that had CMMS, its utilization was found to be elementary. CMMS end users and consultants can use the findings of this study in enhancing the success of CMMS implementation and utilization.

Key Words: Computerized Maintenance Management System, CMMS, process industry, maintenance, Replacement Asset Value, RAV, Pakistan

1. Introduction

Running smooth operations is every manager's desire and ultimate responsibility. To fulfill this desire, from designing to maintaining a reliable system, proper maintenance management is pivotal. Maintenance management ensures smooth flow of material and information in every supply chain and its importance further increases if it is related to the process industry – where large volumes are handled. In such scenario, a shortage of required product due to unavailability of plant/ equipment not only results in huge loss to company [1] but also to the economy. Fertilizer, if for example, is not available in ample quantity during harvesting season, then the government will be forced to spend huge amounts of funds on its import. Also, the required targets of agricultural sector may not be met. Similarly, if power plant operations are not reliable, local industries dependent on power will suffer. This can be alarming, especially for Pakistan, where manufacturing sector already contributes less, i.e. 13.6% to GDP [2] and equipment breakdown with employment of used machinery is common place [3].

Optimum utilization and maintenance of equipment are components of higher return on investment (ROI) [4]. Employing appropriate maintenance and reliability regimes can reduce breakdowns and provide more control on production by keeping the machines fit. For managing almost anything, the technology layer is becoming more and more important as it reduces the transactional costs and enhances decision making. Many companies implement various computerized maintenance management system (CMMS) or enterprise asset management (EAM) software packages, expecting smoother operations. Therefore, along with maintenance and reliability regimes, technology enabled management is vital with the rise of concepts such as 'big data'.

Maintenance management in a large industrial operation is complex and has a significant impact on the profitability of the business. Computer-based support to this process i.e. CMMS has almost become fundamental for achieving operational excellence [5]. CMMS properly controls the system by accessing equipment's data and transforming them into information essential for better decision making, especially considering the high complexity of process industries. Globally, attention to CMMS is on the rise [6].

Case studies have reported the adoption of various maintenance regimes [3, 7-10] in different industrial sectors of Pakistan. However, the state of CMMS' adoption, especially in the process industries, is not readily available in literature.

Therefore, this study explores the adoption of CMMS in Pakistan's process industries. A similar survey, mainly based on Spanish SMEs [11], highlighted that 54% enterprises invested in CMMS but only 45% were found using it in spirit. O'Hanlon [12] documented that 57% companies stated about not achieving the expected ROI from CMMS implementation; while, 20% reported success. Main difficulty in the implementation of CMMS is the customization needed to actually adopt it [12]. Data regarding CMMS adoption in the developed world are readily available; however, the same is not true for emerging markets. This study fills the gap of information regarding the CMMS' implementation, utilization and its impact on maintenance performance in context of Pakistan's process industry. It further provides a KPI-based model for sustaining a disciplined maintenance program that can deliver success.

1.1 Study Objectives

The specific objective of the study is to explore the implementation and utilization status of CMMS in Pakistan's process industry with focus on determining:

i. Companies with and without CMMS implementation;

ii. Purpose of and maturity in CMMS' utilization;

iii. Challenges in CMMS' implementation and utilization, and;

iv. Performance of companies with and without CMMS on strategic maintenance KPIs.

The structure of this paper is such that the next section will present a literature review around process industry, maintenance management and CMMS. Section 3 will discuss the research methodology adopted for achieving the study's objectives. Subsequent section manifests the results of the research. Last sections provide recommendations and conclusions especially for CMMS end users and consultants.

2. Literature Review

The opening sub-section will present a discussion around process industries. Then, the literature on maintenance and CMMS is presented. To assist the reader in exploring this topic in some depth, the next sub-section will share global maintenance KPIs and benchmarks. It closes with a brief definitions of various maintenance strategies.

2.1 Process Industry

Process industry is a capital intensive industry, where asset utilization and management has enormous impact on financial performance. These industries have processes such as mixing, separating, forming and chemical reactions [13, 14]. Batch process industries have high "work in process (WIP)" whereas continuous flow process industries have long setups with large batch sizes [15]. They are less flexible to change and have single routing, thus, simple scheduling.

Process industries have high inventory levels; therefore, have less than 10% material efficiencies and several non-value adding operations up-to 95% [16]. Manufacturing cannot be controlled on lean principles, that easily, in process industries due to typical operational characteristics [17]; however, just-in-time (JIT) can be very helpful for inventory control [18]. Typical operational characteristics include: continuous material flow; very large and inflexible equipment; dependence on time and temperature, and; high volumes with low product variety [19]. Therefore, a system is needed to maintain all the assets at maximum reliability.

2.2 Maintenance and CMMS

Equipment maintenance is a significant part of operating costs in most industries but its impact is often under-estimated. Its hidden impact upon business, follows the iceberg model to determine the total cost of ownership (TCO) [20]. Weinstein et al. [21] has discussed an application of cost of quality (CoQ) concept to determine cost of maintenance (CoM). In order to reduce these maintenance relevant hidden costs, companies need to shift from reactive to proactive reliability based approach. It helps if available maintenance data are converted into valuable information for increasing equipment effectiveness and optimization. It is only possible if the data are collected and reported in a structured way without any manipulation; and this is where the need of a well implemented CMMS or EAM becomes apparent.

Cato and Mobley [22] defines CMMS as an integrated set of computer programs and data files designed to provide a cost effective means of managing the massive maintenance data in a standardized way. Common features of a CMMS include: work orders' management; planning and scheduling function; budget/cost function; spares management, and; key performance indicators (KPI) [12]. CMMS has evolved over the last three decades from elementary asset tracking and preventive maintenance functionality to enterprise maintenance information system. This system is described as enterprise asset management (EAM) that focuses on increasing equipment availability, performance and product quality, and reducing maintenance expense. A properly utilized CMMS can assure proper maintenance of capital investments i.e. plant equipment [23].

CMMS successfully increases the long term productivity and competitiveness [24]. More than 300 CMMS are reported on the software market with different technical functionalities [25]; and the determination of CMMS requirements are challenging to be defined [26, 27]. According to De Lone and Mc Lean [28], the following drivers can mostly influence the success of an information system such as CMMS:

- The system quality, evaluated as its usability (or user-friendliness), availability, reliability, adaptability and response time;
- The information quality, evaluated by the degree of completeness, comprehension, customizability, importance and security, and;
- The service quality of the IT department (or external service provider) and personnel.

These factors can influence noticeably the intention to use and the user satisfaction. This study, similarly, aims to determine the motivation for CMMS utilization in the process industry of Pakistan about which less is known.

2.2.1 CMMS Implementation Challenges

Implementing CMMS is a straightforward task; however, failure rate is extremely high [29]. Success requires an implementation strategy and training. Like other process improvement interventions, CMMS also requires top management as a champion and then everyone's commitment follows [20]. Each element of various processes such as, equipment, employee, maintenance task, and task's procedure should be properly coded and integrated [12].

Wrong implementation of CMMS can enhance the time and cost of carrying out maintenance activities. Common errors, made during CMMS implementation, that can cause more problems later are [20]:

1. Implementing in a company with low readiness;
2. Perceiving CMMS as a "strategy" instead of just a "tool" for maintenance management;
3. Inadequate IT infrastructure;
4. Failure to convince top management about CMMS' benefits for sustainable support during long implementation time;
5. Not recognizing the requirement for a well-established change management process, and;
6. Insufficient resources for implementation [29].

Other barriers are the expensive upgrades/ updates and this expectation that CMMS will magically resolve all maintenance issues [29]. Implementation of CMMS usually requires hours of exercise but the purpose is often ignored. Also. the roll over phase requires constant tracking and follow up, as the legacy systems are being abolished during this phase. Many companies utilize only available in-house resources for implementation; however, it is unrealistic considering the volume of work [20].

2.3 Global Maintenance Benchmarking

The global benchmarks measure operating asset performance of production or process equipment, utilities, support, and related assets. A maintenance performance measurement system should have the right mix of leading and lagging indicators [30]. Weber and Thomas [30] can be referred for a list of 26 maintenance KPIs along with their world class target levels to benchmark. Here, we will discuss two KPIs in detail which are focused in this study.

2.3.1 Maintenance cost as a proportion of replacement asset value (RAV)

RAV is the present cost of replacing an asset if we plan to remove it tomorrow [4, 31]. The ratio of maintenance cost to RAV is known as %RAV. If %RAV of a company is above 20%, then it's better to buy a new plant after every five years. At 2%, the operations can be done for 50 years before maintenance expenses surpass the cost of the plant. At high %RAV, plant and equipment becomes expensive to maintain and reflects either aggressive product or environment. Mathematically, %RAV is defined as:

$$\frac{TMC}{RAV} = \frac{Total\ Maintenance\ Cost}{Replacement\ Asset\ Value} \times 100 \quad (1)$$

Where,

1. Total maintenance cost is comprised of total repair and maintenance cost, spares cost, and labor cost.
2. RAV consists of property, plant and equipment value, and accumulated depreciation.

According to McNair [31]:

- 3% RAV can be reached with the right business processes, tools, skills, knowledge and spirit;
- 2% RAV is reachable if operations and maintenance team-up, and;
- 1% RAV requires paradigm shift throughout the business about the way to design, operate and manage your operation.
- A 'sweet spot' has been defined to lie between 1.75-2.5%. Moreover, to spend too low on maintenance is not considered wise either.

2.3.2 Inventory value as RAV percentage

Maintenance, repair and operations (MRO) is a concept that considers tests, measurements, replacements, adjustments, and repairs intended to retain or restore a functional unit. The value of MRO material stocked is a basis of another vital KPI [4]:

$$\frac{Inventory}{RAV} = \frac{Spares\ Inventory}{Replacement\ Asset\ Value} \times 100 \qquad (2)$$

Where,

1. Spares inventory is reported as "Store, Spares and Tools" in annual reports
2. RAV consists of property, plant and equipment value and accumulated depreciation.

2.4 Enterprise asset management (EAM)

If CMMS is commonly used throughout various facilities of an enterprise then it is termed as enterprise asset management (EAM). This is especially beneficial for a company having plants in multiple locations, where a separate CMMS at every location will bring numerous disadvantages. Maintenance strategies such as condition based maintenance (CBM), reliability centered maintenance (RCM), total productive maintenance (TPM) and tracking of KPIs can be effectively deployed through EAM. EAM was first developed in 1990s; while CMMS was coined in 1970s. Today, these terms are used interchangeably [4].

2.5 Maintenance strategies

Maintenance management has gone through an evolution. A number of classifications define this evolution, such as: according to time of intervention (i.e. reactive or proactive) [32], or according to condition-monitoring versus component's importance matrix [33]. Breakdown and corrective maintenance strategies are reactive approaches. While, preventive /time-based, CBM and RCM are proactive approaches. Moreover, a cultural but innovative Japanese approach is TPM. Chopra et al. [1] defined three levels of maintenance strategies' implementation. They found that 90% of their sampled process industries were using low to medium level maintenance strategies. CBM, RCM and TPM are briefly discussed next.

2.5.1 Condition based maintenance (CBM)

CBM involves monitoring the condition of mission and safety critical parts to avoid hazards rather than following a fixed maintenance schedule [34]. CBM examines an asset's condition to decide which corrective action is needed to be performed when certain indicators show signs of failure. This approach has not been systematically utilized even in Europe's process industry, majorly due to high cost of implementation [32]. CBM can also be managed remotely using geographical information systems (GIS) [7].

2.5.2 Reliability centered maintenance (RCM)

RCM determines what must be done to ensure that an asset continues to perform as per expectation in its present operating context [35]. It formulates a maintenance strategy by selecting the right mix of corrective maintenance, scheduled (or preventative) maintenance, and CBM to fully support the reliability of the system in any given operational environment. RCM is a structured methodology that seeks to answer some fundamental questions: current performance standard of the asset?; its failures, modes /causes, and effects?; how much a failure matters?; suitable proactive actions?, and; what if no proactive action can be found? [29]. RCM is employed in a system's designing phase, then for further refining the maintenance strategy throughout the systems engineering process and finally in the initial fielding of the system [35].

2.5.3 Total productive maintenance (TPM)

TPM involves everybody in the company and not just the maintenance department. It is a more cultural initiative, which is a building block of total quality management (TQM) and lean manufacturing [36]. Daily, it proactively provides comprehensive maintenance for all productive equipment [36, 37] by integrating equipment and resources ; thus, enhancing productivity cheaply. It is a total maintenance system that covers maintenance prevention, preventive maintenance and improvement related maintenance, with the ultimate goal of preventing losses and waste. Shehzad, Zahoor [8] discussed a case of TPM implementation in a process industry of Pakistan. Research has shown that TPM has a direct impact on improving the overall production equipment performance [36].

3. Research Methodology

This study focuses on how CMMS is performing in the process industry of Pakistan. To achieve the objectives, a multi-method research was conducted. The study was initiated with secondary research where a review of the relevant literature was carried out. Subsequently, an analysis of annual reports of publicly listed process industries was done. Companies, having maintenance relevant data reported in their annual reports, were selected for research. To determine the values of selected KPIs, the data required include: repair and maintenance cost; asset value, and; spares inventory value. A sample of 62 companies, listed in the Pakistan Stock Exchange (PSX), was eventually drawn. These process industries are of five types: oil and gas (upstream, midstream, and downstream); fertilizer; power; chemical, and; cement manufacturers. Next sub-section will discuss about this aspect of the study. Further details of the primary research via questionnaire will be presented in Sub-section 3.2.

Primary research started with semi-structured interviews of six CMMS consultants. These were conducted for identifying the gaps in implementation and effective utilization of CMMS. Consultants further provided guidelines for the calculation of various KPIs (see section 2.3) dependent on the data extracted from annual reports. Snowball sampling technique was used to identify the relevant consultant. Five interviews were conducted face-to-face, while one was conducted online via video-conferencing along with a long chain of emails. These consultants had at least 16 years of both local and global consulting experience in the asset integrity of process industries.

3.1 KPI Calculations

To gage the maintenance relevant performance, KPIs were then calculated for the 62 selected Pakistani process industries. The same KPIs were further determined for 17 Middle Eastern process industries for building comparisons. These industries were again selected on the basis of the relevant data being reported in their annual reports. Moreover, the selected KPIs were compared with the global benchmarks stated in literature. A consultant highlighted a shortcoming of this analysis:

"…Unfortunately, publicly traded company annual and 10k reports are inconsistent from company to company…"

KPIs' calculations, based on the data reported in the annual reports, followed the assumptions discussed below:

1. Present value of whole plant is needed to determine accurate RAV. For separate equipment, it is somehow easy to determine as compared to whole facility having various equipment. For RAV calculations, cost of a particular year was considered as reported under the heading "property, plant and equipment (PP&E)". However, this approach's weakness was identified by one consultant:

"…In my opinion, please remember the annual report PP&E value is most likely depreciated value…"

The consultants were more inclined to use the "insurance value", which was unavailable in the annual reports. One consultant highlighted this challenge:

"…I used the 'insurance' value for the plants, but I was an employee inside the company, I did not have to rely on public domain information…"

These comments are in line with the challenges mentioned by Bradbury, Hsiao [38] regarding financial reporting: line items beyond the minimum standard requirements are not mentioned and these reports are written for different audiences having different experience levels. Subsequently, this study went forward with calculating RAV from the annual reports, as no other source was available to provide insurance and depreciation values, if applicable. This possible limitation should be kept in mind while reading the numbers extracted from annual reports for this KPI.

2. For total maintenance cost estimation, calculating maintenance labor cost was a challenge, as this information was missing in the annual reports. Labor cost was then calculated as per the recommendations of the consultant:

"…I have commonly seen labor:material ratios range from 40:60 to 60:40…"

The ratio used was 40:60. The ratio with modest figure for labor costs was chosen considering the fact that labor costs are lower in developing countries. Material cost was known therefore, it helps in determining the labor cost.

3. Readiness in adopting CMMS was gaged as a function of ISO certifications and activities such as reward and recognition program, and recreational activities.

Only the KPIs reflecting strategic level business performance were in focus for this study. Other operational KPIs, which either explain specific equipment behavior (like MTBF and MTTR), or departmental efficiency on tactical level are out of scope.

3.2 Survey Questionnaire

Primary research was continued with questionnaire based survey. In light of the interviews and KPIs' calculations, a survey questionnaire having 10 questions was developed to achieve the remaining research objectives. The questionnaire was further discussed with academicians, and practitioners to maintain its quality. The selected 62 companies were approached via telephone. Survey respondents were CMMS end users – maintenance engineers who are the primary users of such a system. It was a self-administered telephonic survey.

Interviews, questionnaire and analysis of annual reports were the multiple methods of research that were used. These methods provide the triangulation needed in validating the results.

4. Results and Discussion

This section will present the results and analysis around each objective sequentially in the form of sub-sections.

The 62 process industries included in this study are of five types. Figure 1 shows the distribution, which is dominated by chemical and

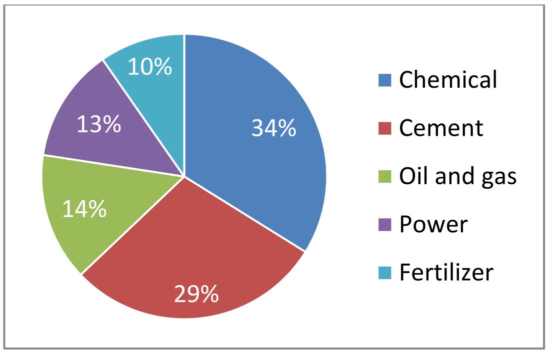

Fig. 1: Types of process industries sampled

cement industries with 34% and 29% representation respectively.

4.1 Types of CMMS

The types of CMMS, with their frequencies, that are being used in the sampled process industries are shown in figure 2. The most used CMMS is SAP (24%) which is followed closely by Oracle (19%). 8% are using Maximo while 5% have customized solutions. 44% companies are not using any CMMS.

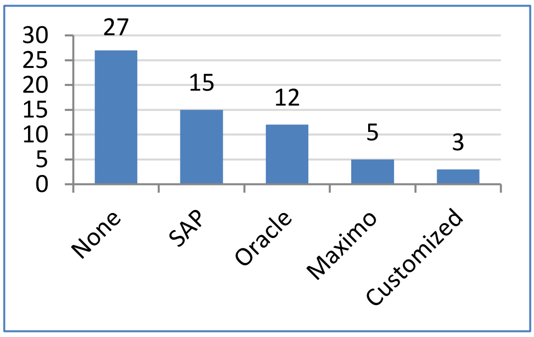

Fig. 2: Types of CMMS installed in sampled process industries

All the following survey results pertain to the 56% process industries having CMMS.

4.2 Purpose and maturity

As far as the purpose of utilization is concerned, it was found that 97% of the companies are using CMMS for both corrective and preventive maintenance activities. However, only 3% were found to be using it for other functions as well, such as stores management of spares.

Maturity in using CMMS is gaged in terms of years of usage. Approximately 86% (see figure 3) of the companies having CMMS, are mature, as these are using it for more than three years. It means that these companies have already passed the challenges of the implementation phase and are now sailing smoothly. Usually, the phases of implementation, go-live and normalization cumulatively take multiple years of effort [29].

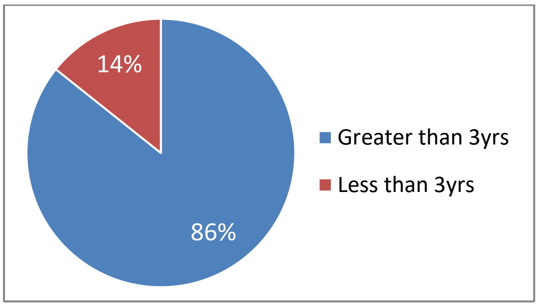

Fig. 3: Years since CMMS is in use

4.3 Tracking KPIs

Regarding monitoring of maintenance related KPIs, it was found that 40% of the companies are not tracking any KPI through CMMS (see figure 4). 40% of the companies are tracking the standard KPIs only, which are generally a part of every CMMS software solution. Standard KPIs include: total number of maintenance work orders generated; number of corrective and preventive work orders pending, and; percentage completion of maintenance work orders in a month or year. Only 11% measure machine specific KPIs, like MTBF and MTTR, apart from standard KPIs. 9% industries further track directional KPIs like CM:PM ratio – describes status of maintenance management.

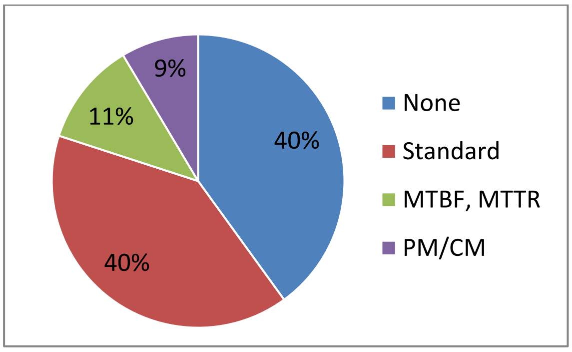

Fig. 4: Maintenance KPI's tracked

Subsequently, the knowledge of preventive maintenance work orders' completion is gaged. Figure 5 shows that more than 50% respondents have no idea of this completion percentage. 48% respondents showed awareness about this KPI; out of which, only 17% identified their work orders' completion greater than or equal to 95%, while, others have more pending maintenance work orders.

Though 86% (see figure 3) companies are using CMMS for more than 3 years, its use for

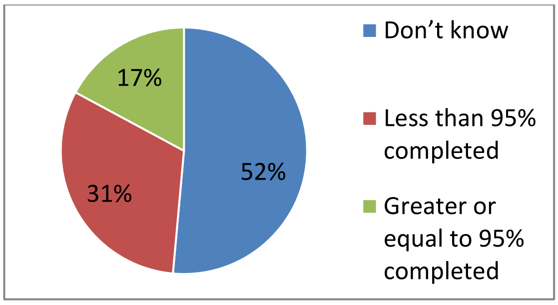

Fig. 5: Preventive maintenance work orders completed in companies having CMMS

analysis is low. Figure 6 shows that 66% companies does not carry out any root cause analysis (RCA) through CMMS. Whereas, 26% of the respondents agree that they perform RCA via CMMS. Furthermore, 8% carry out RCA manually.

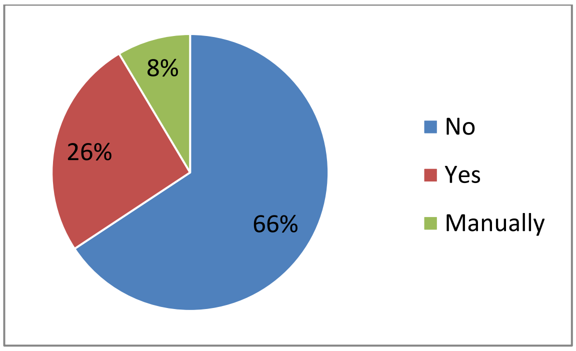

Fig. 6: Root Cause Analysis carried out using CMMS

It was further found that 46% companies calculate repair and maintenance costs through CMMS. While, 55% do not use it for extracting or reporting this information.

In light of figures 3 to 6, it can be concluded that albeit 86% companies are using CMMS for more than three years, but its utilization is still elementary. The full potential of CMMS – especially for analysis and decision making purposes – has not yet been unleashed.

4.4 Challenges

The CMMS consultants interviewed defined various challenges during CMMS implementation. A frequency diagram in figure 7 shows these challenges. Majority of the interviewees found 'weak understanding of CMMS' and 'lack of data cleansing' – master data provided by users require detailed review – to be major challenges during implementation. The consultants further stated that machinery specific KPIs are present in various commercial-off-the-shelf (COTS) CMMS or ERP. Regarding challenges during utilization, they commented that some CMMS require the user to run complex queries (formula or text) for searching desired information; thus, making it difficult to use. In some ERP, there is no provision for calculating maintenance KPIs. Furthermore, overall equipment effectiveness (OEE) can be calculated through CMMS but it is not a norm because of lack of integration with plant and production data. Another challenge was the awareness of the users in inserting and editing data to avoid 'garbage in and garbage out' risk. This lack of awareness provides a hint towards why the mature sampled process industries are not using the CMMS fully. When data entry becomes questionable then its utility – as an input to decision making – decreases.

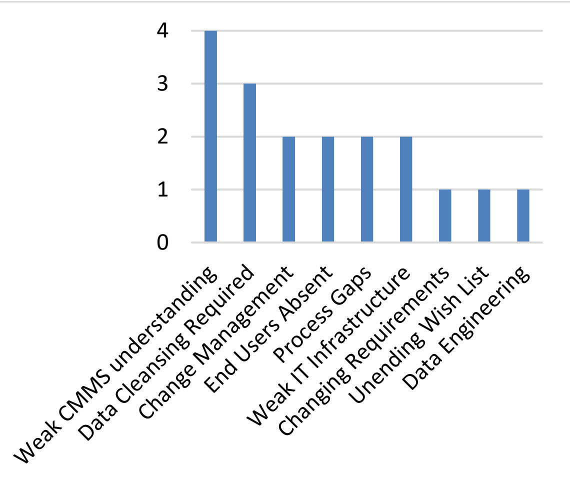

Fig. 7: Challenges in CMMS implementation

4.5 Analysis of Annual Reports

Now, the results of annual reports are analyzed. The annual reports of the 62 sampled process industries were analyzed for calculating various KPIs presented in section 2.3. According to a survey, most of the Pakistani infrastructure firms consider that their performance measurement systems need urgent attention [39].

The average TMC/RAV ratio of all the process industries that were using COTS solutions – SAP, Maximo and Oracle – was found to be 3.74%. A comparison of TMC/RAV Ratio of companies having COTS CMMS and those having no CMMS can be observed in figure 8. It can further be deduced that the maintenance costs, in companies having COTS CMMS, will equalize equipment value after approx. 26.7 years (i.e. [1÷3.74]×100 = 26.7). The same is approx. 17.6 years for companies without CMMS. Approx. 61% companies have TMC/RAV ratio greater than 3%, whereas the mean value of all 62 sampled Pakistan's process industries is 4.6% which describes that there is an opportunity for improvement in maintenance management practices.

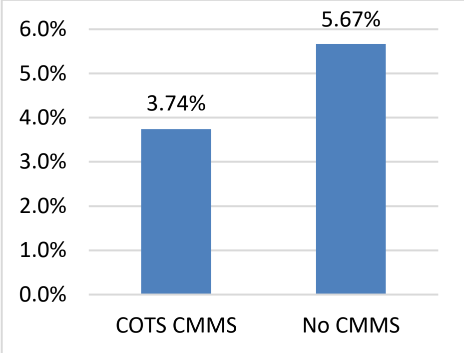

Fig. 8: TMC/RAV Ratio of companies having COTS CMMS versus no CMMS

We were further interested in knowing the TMC/RAV ratio of companies that are or aren't tracking various KPIs via CMMS. Figure 9 presents these results. It can be seen that TMC/RAV ratio is close to 3% for companies that have CMMS and simultaneously these are tracking specific KPIs and completion of preventive maintenance work orders. For enhanced comprehension, figure 9 should be observed in light of figures 4, 5 and 8.

On disaggregate level, TMC/RAV ratios of all the types of process industries included in this study are shown in figure 10. Fertilizer and power industries are leading in TMC/RAV ratio, as their ratios are 2.9% and 3.2% respectively. Similarly, oil and gas, and chemical lead in terms of their Inventory/RAV ratios of 3.1% and 3.3% respectively.

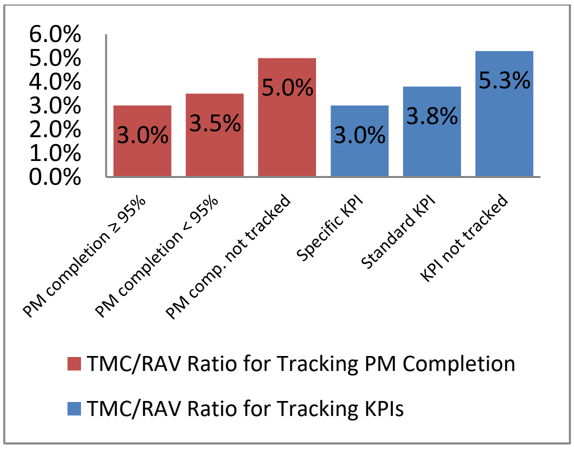

Fig. 9: TMC/RAV ratio of companies with reference to KPIs and PM completion

For Pakistan, it is 4.6% (see figure 11) as compared to 1% that of Middle Eastern counterparts; however, the global benchmark is 2.5% [30].

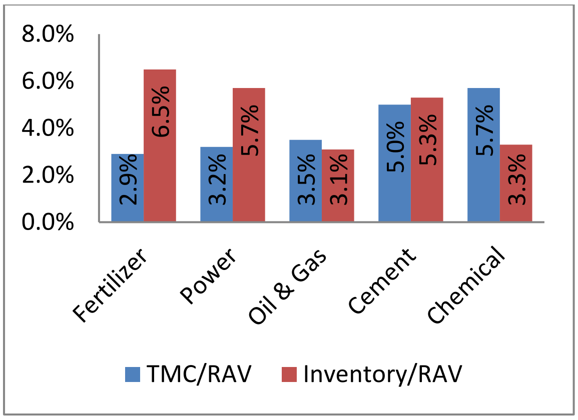

Fig. 10: TMC/RAV ratio of the sampled types of process industries

The global benchmark of spares inventory/RAV ratio is 1.5% [30]; however, its mean value for Pakistan is 4.5%, as compared to 3% that of Middle Eastern companies. Reviewing this number, one consultant noted:

"…That is high by USA and EU standards. In the USA, a typical plant will be 1.5%. Best practice is less than 1%. In countries that have to import their capital equipment, with spare parts having long lead times, one would expect to have a higher than average Inventory to RAV…"

So, import of spares with long lead times pose a challenge for this KPI to be effective in developing markets, where capital equipment and spares are frequently imported. Granular level analysis showed that mean Inventory/RAV ratio of 80% Pakistani companies is 4.6%. Approx. 14% companies have inventory levels lower than the global standards and thus, Inventory/RAV ratio below 1.5%. Remaining companies (around 6%) are close to the global benchmark. Performance of Pakistan's process industries on both the KPIs identifies an opportunity area of improvement by revisiting maintenance and inventory management practices.

Annual reports further explain that companies having mature CMMS along with certifications – ISO 9001, 18001 and 14001 – have mean TMC/RAV ratio of 3.86%. While companies having neither CMMS and nor certification have this ratio standing at 4.9%.

Approx. 32% companies with CMMS have at least one certification. 54% have all three certifications: thus, indicating their commitment towards Quality, Health, Safety and Environment (QHSE). Certifications show that these companies already have an enabling environment for technology. On the other hand, 14% of companies having CMMS do not have any ISO certification.

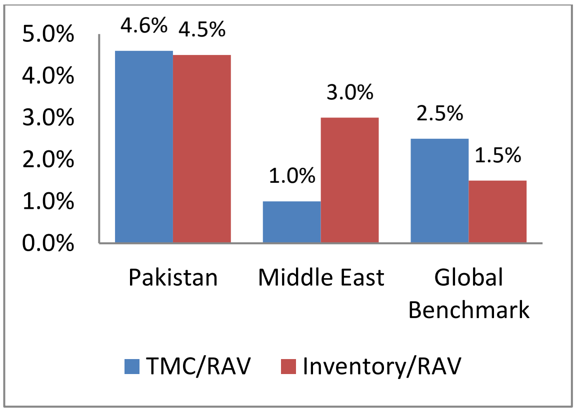

Fig. 11: Comparison of Pakistani and Middle Eastern companies with reference to global benchmarks

Approx. 48% of the companies without CMMS do not have any certification; whereas, 22% have at least one and 30% have all three QHSE certifications. This describes that majority of these companies are not ready for CMMS implementation due to lack of integrated management systems.

Moreover, annual reports show that approx. 49% of companies with CMMS have no reward and recognition system nor do they arrange recreational activities whereas 34% of the companies have both. While, 89% of the companies without CMMS neither have reward and recognition program nor arrange recreational activities for the employees.

Companies having CMMS, with all three QHSE certifications, reward and recognition of employees, and that arrange recreational activities have TMC/RAV ratio of 3%. This shows that reward and recognition system along with recreational activities motivates employees professionally. This is in line with the suggestion of van de Kerkhof [32] of equally investing in people along with technology and systems.

5. Recommendations

Recommendations based on qualitative data analysis of interviews are as follows:

- It is better if consultants share the ROI calculations with end user before CMMS implementation so that a better investment decision can be taken. On proper implementation, the payback period for a CMMS is taken as less than 1 year [20] or 1-2 years [29].
- Provision of calculating maintenance specific KPIs is available in various CMMS; however, some need customization which only happens if the user asks for it.

- There is a need to spread awareness about the new and customizable features of CMMS, which has also been suggested by [6]. Some less used features in Pakistan are: equipment vendors' data integration in CMMS; supporting RCM and risk based inspection (RBI); real time monitoring of asset, accessed using mobile and 3D technology.
- Training around global maintenance KPIs and benchmarks is required, as unawareness is also evident from the survey where only 20% of users track equipment specific and directional KPIs through CMMS.
- RAV concept can be used during maintenance budget planning and inventory optimization.
- TMC/RAV ratio is more effective for tracking maintenance management throughout an asset's life cycle. Consultants defined a model, based on this KPI, for continuous improvement of the maintenance function (see Figure 12).

6. Conclusions

Maintenance has a fundamental place in establishing reliable operations. However, its associated costs, whether it be for scheduled or breakdown, are mostly hidden. This builds a case of adding the technology layer in terms of computerized maintenance management system (CMMS). This paper aims to explore the current status of CMMS in the process industries of a developing country. For this study, data were collected via questionnaire from 62 publicly listed companies along with an analysis of their annual reports. Moreover, six interviews of CMMS consultants were conducted. It was found that 56% of the sampled companies had a CMMS running, while 44% had no such solution. The key performance indicator (KPI) of TMC/RAV (total maintenance cost / replacement asset value) was further determined, which was found to be 3.74% for companies with CMMS and 5.67% for companies with no CMMS; considering the global benchmark of 2.5%. The challenges to CMMS implementation included unawareness about function of CMMS, erroneous data and weak change management. Even in companies that had CMMS, its utilization was found to be limited, which is similar to what Mobley [29] found as 9% overall utilization. This suggests that there is an immense opportunity for improvement in maintenance management practices in Pakistan. This will further strengthen the input process of predictive data analytics for better business decision making.

A future study can be conducted by including other types of process industries, such as paper, steel and textile. Subsequently, challenges regarding KPI calculations, discussed under research methodology section, needs to be overcome. Future research should segregate new facilities from older ones, as the KPIs are age dependent. A correlation of maintenance relevant KPIs and financial ratios (e.g. current ratio) can further be established using data reported in annual reports. Moreover, this study has identified low utilization of CMMS in the process industry of Pakistan; however, deeper reasons apart from lack of awareness, remain unknown for future researchers to explore.

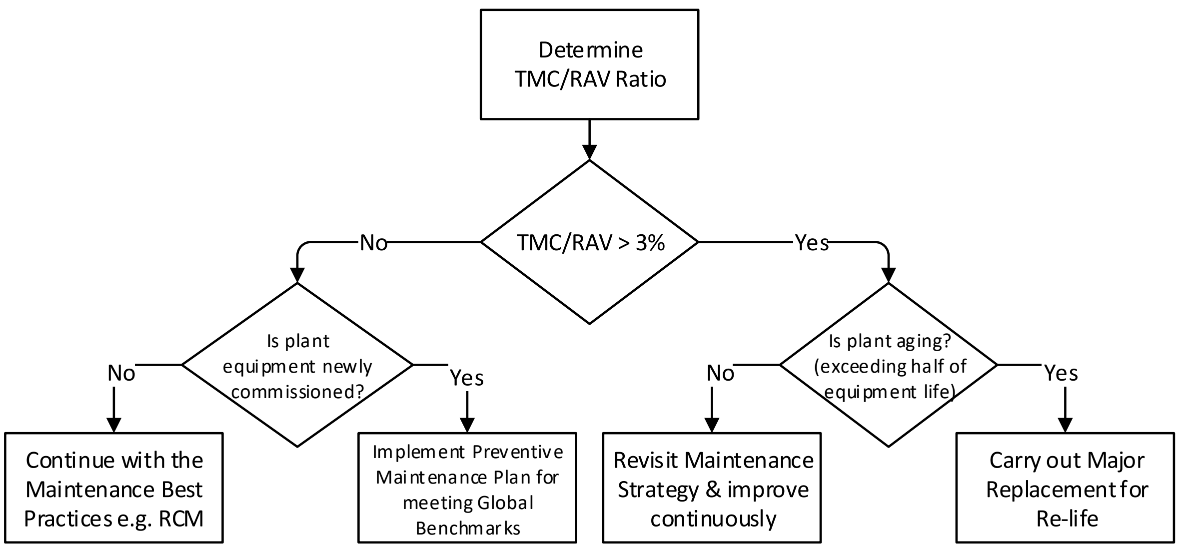

Fig. 12: TMC/RAV based maintenance improvement model

7. References

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